Cortical Control of Neural Prostheses

Quarterly Report #10

April 1, 1999 - June 30, 1999

(Contract NIH-NINDS-NO1-NS-6-2347)

Submitted to the Neural Prosthesis Program
National Institute of Neurological Disorders and Stroke
National Institutes of Health

By

Andrew Schwartz, Ph.D., Principal Investigator
Gary Yamaguchi, Ph.D., Co-Principal Investigator
Daryl Kipke, Ph.D.
Jiping He, Ph.D.
Jennie Si, Ph.D.
James Sweeney, Ph.D.
Stephen Helms Tillery, Ph.D.

The Whitaker Center for Neuromechanical Control
Bioengineering Program
Arizona State University
Tempe, Arizona 85287-6006

Work Performed During the Reporting Period

In this reporting period, we continued to record spike data from our previously implanted monkeys H and K. These animals were implanted with micro-wire arrays consisting of Teflon-coated stainless steel wires (50 microns in diameter) arranged in two linear arrays of eight wires each (spaced two hundred microns apart). The stainless steel electrode arrays were purchased from NB Labs. Monkey K was also previously implanted with a new prototype electrode that has a self-contained microdrive.

The NB electrodes that were implanted in the left hemisphere of animal H on 9/9/98 continue to produce data. In that surgery we implanted 4 NB electrodes, providing up to 64 independent channels of neuronal data. We are still able to record 15 neurons from that implant. None of the implants on the right hemisphere (4 NB electrodes and one microdrive) are producing data. Our impression is that the remarkable results from the left hemisphere implant are related to better protection of the cortical surface both before and after the implantation.

There are multiple groups working on the analysis of this data. We have developed and performed preliminary tests on three further types of analysis, one deterministic technique and two classification schemes.

The deterministic technique starts with the standard population vector analysis (PVA). We have extended this method by incorporating a measure of synchronous firing between all pairs of neurons in a data set. We have found that the synchrony between neurons is occasionally directionally tuned. By making use of this as an additional signal in the PVA, we can improve the fit of the predicted trajectories to the actual trajectories.

One of our classification schemes uses a fuzzy logic engine to associate categories of multiple-neuron firing rates with categories of movement. We have found that using as few as 16 neurons, we can reproduce movement trajectories that generally terminate in the correct octant in the center->out task. However, the mean endpoint errors in these trajectories have been rather large (1.5 – 10 cm for a 13 cm movement), and the method has a large computational overhead. The accuracy problem may lie in part with the small numbers of neurons used thus far in the analyses, and so we are continuing our efforts with fuzzy logic as we acquire more data.

We have also developed a technique that uses principle component analysis to classify the multiple units in a way that implicitly incorporates temporal profiles of the neural discharge. Using this method, we have been able to reproduce neural predictions with correlation coefficients relative to the hand trajectories of 0.8. This method has a high overhead in performing the initial analysis of the data, but once the principle components have been established, the computations involved in reconstructing the trajectories are nominal.

The real-time communications for testing the algorithms using the Zebra Zero robotic arm as a test-bed are now in place. We are able to process the data online, send velocity command packets over a serial port at 20 ms intervals, read those packets, and use them to control the robotic arm in real time. Right now, we are focused on reconstructing only the center-out trajectories. At the end of each target-directed movement, we explicitly move the robot arm back to the center position. This assures that we maintain correspondence between the monkey's position and the robot's, regardless of the accuracy of our reconstructed trajectories.

Work anticipated for the Next Reporting Period

We will be implanting the second hemisphere of monkey K early in the next reporting period. In this surgery we will be using stainless-steel wire array implants that are built in-house. The second microdrive array is nearly ready for implantation, and we expect shortly to put it into one of the two monkeys (L & M) that are currently trained in the center->out task.

Our data analysis will continue using fuzzy inference engines, measures of synchrony in the multiple-unit recordings, and the principle component analysis technique. We will also be investigating a novel technique that combines fuzzy logic with neural networks to extract directional information from the cortical signal. In addition to specific effort on algorithms that reconstruct movement trajectories, we will also be seeking quantitative means to compare the merits of these disparate techniques.

We will be attending to the infrastructure of our lab in the next reporting period. Specifically, we will start implementing a database that we can use both for archival purposes and for off-line data analyses. We have also begun to acquire the components of a virtual reality system that will substantially increase the sophistication of our behavioral paradigms. We plan to have an animal training on that system within the next two reporting periods.

Finally, we will evaluate two types of chronically implanted microdrives that we expect will improve the yield of recorded units per electrode. In addition, a multi-site cylindrical probe prototype should be ready for implantation in rat cortex in the next two months. If this probe records units reliably, we will also implant one in monkey cortex. It is clear from our preliminary analyses that an increase in the number of well-isolated units will improve our ability to extract high fidelity representations of arm trajectory.